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‘Partners in Light:’ How Plastics Enabled Fluorescent Lighting and the Modern Office.”

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Abstract

Writing in 1946, Charles Breskin, the editor of *Modern Plastics*, suggested that designers were emerging from the “dark ages” of commercial lighting. While construction in America had lagged during the Depression and World War, scientific advances in many areas of building technology had surged, and new demand for residential and commercial space was matched by the desire for more efficient, comfortable, and mechanized buildings. While advances in building cladding and servicing have been well-covered, one key development—matching chemical developments in plastics with electrical and illuminatory advances in fluorescent lighting—had equally revolutionary impacts on building interiors.

Fluorescent lighting as a technology dated to the late 19th century, but it only saw commercial development with the expiration of incandescent patents in the 1930s. Keen to develop a new market for a product that they could still claim as exclusive, General Electric pushed early fluorescent systems to market by 1934. These lamps offered cool, energy efficient light that was ideal for factories, but they also saw early use in office buildings. Among their benefits was the ease they offered in controlling and directing their light. While incandescent lamps ran hot, requiring heat- and ignition-proof housings of metal, fluorescents could be paired with diffusers, reflectors, and housings made of more easily molded plastic. Underwriters Laboratories approved the first polystyrene holders for fluorescents in 1945, which allowed lighting designers wide latitude in the way fluorescent light could be focused, reflected, directed, and shaded. The first systems to provide truly even light distribution over wide floor and desk areas followed. Along with the ubiquitous sealed curtain wall and perimeter air conditioning units, office buildings of the 1950s quickly took advantage of fluorescents’ easy pairing with scientifically designed housings that enabled regular, gridded ceiling layouts—a key influence in the development of the open plan, modular office.

Introduction

Writing in 1912, illuminating engineer Louis Bell stood at a turning point in architectural lighting. Carbon-filament electric lamps, which produced faltering light of around 16 candlepower and that burned out within a few hundred hours, had been the industry’s standard for over a generation. Tungsten filaments, which had debuted in 1907, offered brighter longer lives, “driving out” carbon filaments from the market despite their greater cost. (2) General Electric, which traced its corporate ancestry to Thomas Edison, established a near-monopoly on tungsten lamp production. It absorbed the National Electric Lighting Association in 1911, taking over its research and industrial center east of Cleveland, Nela Park, where GE went on to improve tungsten alloys, wire coiling, and bulb atmospheres, bringing the cost of incandescent lighting down while increasing its efficiency.

Incandescent fixtures had two intractable comfort problems, however: one visual, and one thermal. To heat tungsten to the 2300°C necessary to achieve incandescence, a narrow filament had to be subjected to a high current, creating resistance. Radiance relies on the physical quantity of tungsten, but resistance requires a narrow cross section. Filaments must, therefore, be long and thin, but they also have to be protected from the outside atmosphere to prevent oxidation. Over time, engineers settled on a tightly wound tungsten coil within a spherical bulb—at first evacuated, but later filled with a neutral gas to prevent the filament from evaporating. (3) This turned long, linear filaments into intense point sources of light that could reach 1000fc of intrinsic brightness. Such a powerful source was uncomfortable to view directly and had to be shaded from direct lines of sight by diffusers, louvers, or reflectors, all of which decreased the lamp's effectiveness. The heat that these fixtures emitted, however, was even more problematic. Most of the energy radiated from an incandescent filament is heat—only 7-10% of the electricity that went in to a typical tungsten filament emerged as visible light. (4) Even at its maximum theoretical luminous efficiency, at its melting point of 3655°K, a tungsten filament produced just 53 lumens per watt. Incandescent lamps, however, had to operate at much lower temperatures, since the melting point of the solder that held their base wires together was only 345°F; at this temperature, tungsten filaments produced 16 lumens per watt. (5) The electricity that did not produce shortwave, visible light produced longwave radiation, or heat, some of which heated the surrounding glass bulbs, but most of which was transmitted, along with the visible light, to heat surrounding materials, room fixtures, and occupants. This added to the temperature of surrounding rooms and it restricted manufacturers' options for lamp holders and shades; any material that intercepted and absorbed visible radiation also absorbed radiant heat, which could cause scorching, melting, or even ignition close to hot bulbs and filaments.

General Electric and their closest competitor, Westinghouse, responded to these problems by matching more powerful lamps, which offered modest improvements in efficiency but had shorter filament lives, with features that reduced direct glare including silvered caps or frosted bulbs. Incandescent fixtures, typically surrounded a lamp with metal or glass enclosures that diffused or reflected the filament's piercing brightness. But these were only marginally successful. By 1939, Architectural Record shared the frustration of illuminating engineers and architects with the limitations of incandescent lighting. "Efficiency of the tungsten-filament lamp," it noted, "is now approaching its practical limits." (6) This frustration was already being addressed, however, by the spectacular debut of new "firefly-like" lamps at the New York World's Fair and the Golden Gate International Exposition San Francisco. (7)

Fluorescent Lamp History and Principles

Since the 1860s, engineers had known that certain gases—neon in particular, but also helium and sodium vapor—emitted visible radiation when energized. The Cooper-Hewitt lamp, which debuted in 1901, relied on this effect, as did sodium-vapor lamps, which appeared in commercial form in 1931. (8) Pure electric discharge lamps were inefficient and difficult to operate, however, and the light they produced was limited in color. They were appealing since they contained no fragile filaments, but saw little use outside of advertising and industrial applications. French scientist Alexandre Edmond Becquerel noted in 1859 that adding 'luminescent solids' to discharge lamps added impressive candlepower. He suggested that such solids could be spread on glass bulbs' inside surfaces to boost the lamps' efficacy. (9) As early as 1896, Edison himself experimented with electric discharge lamps using bulbs coated with an oxide of tungsten that fluoresced when bombarded by energized gas particles. This produced similar intensities of light but at lower energies—and thus cooler temperatures—than either incandescent or pure electric discharge lamps. The difficulties of producing these coatings and the popularity of incandescent lamps had left Edison unenthusiastic.

To provide rapid starting and consistent operation, fluorescent lamps consist of glass tubes lined with phosphor-rich powder and filled with a low-pressure inert gas and a small quantity of mercury, which vaporizes in the near-vacuum of the tube. Electrodes at each end pass an arc through this gaseous mixture, which causes the mercury to emit radiation across the spectrum, with a particular ultraviolet intensity. While this alone produces some visible radiation—the electric discharge effect—the invisible, ultraviolet radiation that accompanies this excites phosphors in the tube's coating, which in turn produces visible light. By adjusting the phosphors' chemistry, engineers can adjust the emitted light's color and intensity. While electric discharge lamps required several ounces of mercury to produce adequate light, fluorescents required only a few milligrams. Argon serves as a 'starter' for the tube and, as it becomes energized mercury floating in its midst also begins generating radiation. While the principle of fluorescents was thus simple and efficient, the actual process required technical innovation and some engineering finesse. Because fluorescent lamps became more efficient conductors as they energize, they require electric ballasts to prevent runaway electric currents. Starting requires a precise mixture of argon and mercury vapor, and fluorescent lamps are sensitive to temperature—mercury emits radiation most efficiently at 45°C (113°F).

Despite the delicate engineering required, fluorescent lamps offered three advantages over incandescent lamps that kept researchers interested in the principle during the incandescent era. First, by spreading their output over the larger surface area of a bulb instead of concentrating it in a single point-source filament, they addressed incandescent lamps' persistent problems of glare. Second, whereas incandescent lamps' maximum life peaked at 1000 hours, lifespans of fluorescent lamps averaged between 2500-5000 hours, reducing maintenance and replacement costs. (10) Finally, fluorescent lamps offered improved efficiency over incandescent lamps. By 1943, improved tungsten filaments still converted less than 7% of their electricity consumption into useful light in standard, 100-watt lamps. A 40-watt fluorescent lamp, by comparison, converted more than 18% of its energy into visible light, producing between 50 and 70 lumens per watt, or three to four times that of incandescent lamps. (11) This reduced the amount of electricity needed to illuminate any given space, but each watt represented a fixed quantity of longwave radiation—3.415 British Thermal Units of heat for every watt-hour of energy consumed—being discharged by the lamp. (12) 100-watt Incandescent lamps produced bulb temperatures of 250°F, compared to 100°F to 120°F for a 40-watt fluorescent lamp that produced roughly the same output. As thermal comfort became an area of scientific study and concern with the advent of air conditioning in the 1920s and 1930s, heat produced by incandescent lighting proved to be a troublesome factor in environmental engineering. In 1950, Progressive Architecture estimated that each incandescent lamp in a building added between $14 and $23 of increased air conditioning capacity. (13)

Fluorescent lamps' advantages would only reach the market, however, with dedicated engineering and experimentation. There was little momentum to research a better solution while General Electric and its licensees saw comfortable growth in the incandescent market. As late as 1935, with no viable alternatives on the market, domestic and commercial customers remained "quite satisfied" with incandescent technology's gradual—but slowing—improvements in efficiency and cost. (14) Over the next few years, however, advances proceeded rapidly, sparking anticipation among designers and frustration with incandescents' stalled-out technical advances. GE and its primary licensee for tungsten-filament lamps, Westinghouse, had enjoyed a near-corner on the lighting market, with 78% of the nearly 700,000,000 lamps sold in the United States coming from one of the two manufacturers. But the two companies had mounting concerns. The American patent on tungsten filaments—filed by two Austrian citizens, purchased by General Electric, and granted in February 1912—expired in 1929. (15) Agreements with glass suppliers such as Corning kept the two companies ahead of their competitors, but independent manufacturers such as Salem, Massachusetts-based Hygrade posed a growing threat. Hygrade merged with a radio manufacturer named Sylvania in 1931, obtaining a formidable research and development team that sought new avenues into the still fast-growing lighting market.

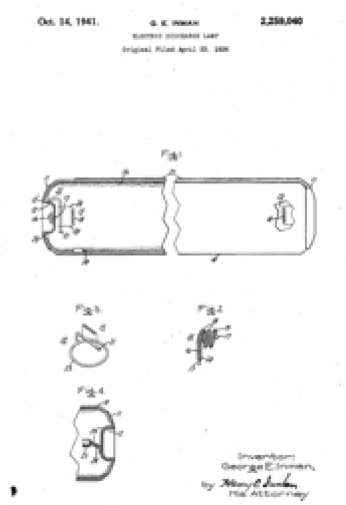

Fig. 1. G.E. Inman's patent for a commercial fluorescent lamp, filed 1936.

General Electric's research farm at Nela Park remained the premiere site for lighting innovation, though, and in 1934 they began work on alternatives to the newly competitive incandescent marketplace. In October of that year, physicist Arthur Compton saw a rudimentary fluorescent lamp in an English laboratory and, as a technical consultant on retainer to GE, he urged executives at Nela Park to pursue the idea commercially. Researchers led by George Inman began work that November, building on tentative but fruitless experiments with fluorescence in electric discharge lamps done by GE engineers in Schenectady, by those that Compton had seen in England, and by French scientists who had sought to correct the green color of mercury discharge lamps. By December, the GE team developed a working 10-inch lamp that proved fluorescent's feasibility and the company launched parallel initiatives to develop ballasts and manufacturing tools. Westinghouse and Sylvania followed GE's lead, as did Dutch manufacturer Philips. Three years of fine-tuning followed GE's prototype; internal correspondence revealed that the prodigious performance promised by fluorescent technology only occurred with a frustratingly delicate balance of conditions:

"Within the range of acceptable bulb sizes, the designer (of fluorescent lamps) must compose the electrical characteristics to produce the desired lumens per foot, brightness per square inch of tube, and over-all efficiency. He must adjust the electrical relationship of current, voltage, lamp loading (which is the wattage-diameter-length relationship), and related gas pressures so as to provide reliable starting and satisfactory regulation under operating conditions as to temperature and humidity." (16)

General Electric demonstrated prototype fluorescent lamps at the Illuminating Engineering Society's annual meeting in Cincinnati in September, 1935, at a dinner celebrating the centenary of the U.S. Patent Office in Washington, D.C., in November of that year, and at the American Institute of Electrical Engineering's annual meeting in 1936, though the company's publicists described these in restrained terms, as "a laboratory development of great promise." (17) After work by Philip Pritchard and his team on the precision manufacturing necessary to produce thin, coated, tubular bulbs and to fill these with a near-vacuum of argon and mercury vapor, GE announced in April, 1938, that fluorescent lighting's "efficiencies heretofore unobtainable" would reach the market that spring. Along with Westinghouse, they offered three sizes of lamps—18, 24, and 36 inches—

ranging from 15 to 30 watts. The new lamps' debuts at the World's Fairs in 1939 proved to be a sensation; the New York Times reported that thirty percent of the New York fairgrounds were illuminated by fluorescents offering a visual 'softness' and nuance that contributed to the Fair's signature 'Wellsian fantasy of color.' (18) Much of the Golden Gate Exposition's billion-and-a-half candlepower came from fluorescent lamps as well, in particular the soft pink light that bathed the 'Court of Reflections.' Public response was so enthusiastic that the three companies scrambled to increase production. GE obtained key patents in 1941 and along with its prime licensee, Westinghouse, saw sales increase from 200,000 units in 1938 to 1.6 million in 1939, 7.1 million in 1940, and 21 million in 1941. (19) Upstart manufacturer Sylvania pursued a parallel set of patents, spurring competition that reduced prices by 2/3, raised average lumens-per-watt across the industry from 35 to 50, and increased options in color and size, all by 1942. While GE and Westinghouse concentrated on the lamps themselves, Sylvania offered a "complete unit of light" to its customers, matching their lamps with fixtures that could manipulate, direct, or diffuse their output. (20)

World War II had two determining effects on the fledgling industry. While few of the materials needed for the lamps themselves were embargoed in the U.S., wartime restrictions on metal limited manufacturers' ability to supply fixtures. At the same time, rapid expansion of materiel production for the war effort brought with it increased industrial demand for illumination and here fluorescent lighting proved itself. Industry had already been an early adopter of fluorescent lighting. Large, open factory floors could take advantage of its efficiency, and its diffuse light meant that it required less elaborate fixtures to cast an even illumination over work areas. Perhaps most important, however, plant designers recognized that fluorescent lamps' cool operation matched the increasingly sophisticated climate control systems demanded of precision manufacturing. In 1940, the Austin Company matched one of the country's largest and most complex air conditioning systems with three-lamp fluorescent fixtures throughout General Motors' Allison aircraft engine plant in Speedway, Indiana, citing lighting load as a major factor in their cooling calculations. The factory's ambient temperature—held between 70°F and 78°F throughout the year—and its even, reliable illumination offered by the cooler, efficient fluorescent fixtures enabled "high-speed quantity production methods to the manufacture of airplane engines—which require many precise operations." (21)

Fig. 2. Austin Company's design for the Allison division of General Motors was among the first to use fluorescent fixtures throughout. Architectural Record, February, 1940. 91.

A nearly-contemporaneous factory, also designed by the Austin Company, for Simonds Saw in Fitchburg, Massachusetts, made this pairing explicit. A Carrier air conditioning system provided 400,000 cfm of conditioned air to areas as diverse as sales offices and a forge room. (22) While designers originally planned to illuminate production areas with 650-watt incandescent fixtures when first planned in 1931, a depression-related delay until 1939 made fluorescent lighting's efficiencies available to the project and the factory was ultimately outfitted with 1400 100-watt Cooper-Hewitt fluorescent tubes that provided an even 20 foot-candles throughout. (23) This "manufactured north light," a reference to the desirable, glare-free daylight that factory skylights are often designed to maximize, worked well enough that the entire Simonds complex was designed without windows, its thermal and visual environments both entirely artificial. “The scientific superiority of artificially controlled environment furnished the basis for designing this completely windowless plant,” reported Architectural Record. “Air, light, heat, humidity, and sound are all regulated to provide the best attainable working conditions for employees, and a maximum of efficiency in manufacturing processes.” (24) Simonds estimated that the combination of air conditioning and fluorescent lighting, along with improvements in acoustics, increased worker efficiency by 35%.

These benefits—cooler operation, diffuse illumination, and lower electricity consumption—made fluorescent lighting the system of choice for wartime factories. The Simonds example showed, too, that fully enclosed, windowless factories were feasible, an important design aspect when fears of Axis bombing raids led to blackout conditions at night. “One of the recent romances of American industry is the development of fluorescent lighting,” wrote Lester Smith of the Wall Street Journal in 1942. “Not since Thomas A. Edison invented the incandescent lamp has the art of lighting undergone as radical a change as that which has occurred in the past few years.” (25) Workers in factories during WWII enjoyed more than double the amount of illumination on their tasks as had those in WWI, and in some cases, the new lamps provided up to ten or twenty times the candlepower of previous installations. Ford’s plant at Willow Run used more than 100,000 fluorescent lamps, allowing greater levels of precision and faster production times on bombers manufactured there. “The brightest lights today aren’t found on dimmed-out Broadway,” noted the Journal. “They are in the arms factories where vastly improved illumination is helping war workers chalk up impressive production records.” (26) Some measure of fluorescent lighting’s value to the war effort can be seen in the shelving of persistent anti-trust complaints against GE by the Department of Justice in 1942; continued manufacture of lamps and fixtures was deemed critical by the military, and the case was only resumed in 1953.

Postwar introduction

Fluorescent lamps were limited to military production through the war, but their benefits were anticipated for residential and commercial use. When the war ended the lighting industry had a tremendous overcapacity, bringing costs down and forcing GE, Westinghouse, Sylvania, and other competing manufacturers to find new markets for lamps and fixtures. Manufacturers saw limitless potential in the energized postwar economy; industry produced nearly 41 million fluorescent lamps in 1945, but it also manufactured nearly 800 million incandescent lamps. (27) Department stores were quick to take advantage of the soft, soothing diffuse light of fluorescent fixtures and enthusiastic designers foresaw “handfuls” of “daylight” fluorescent lamps replacing the “dozens” of incandescent lamps in a typical American home. Residential adoption proved slower, but fluorescent lighting’s unique qualities and quirks of their geometry offered a powerful new approach to office lighting, matching radical changes in the way offices were being organized. While the “fireless light” made inroads in homes and stores throughout America in the 1950s, it was in offices, and especially high-rise offices, where it found its most robust market and its ideal architectural application.

Fluorescent lamps were accepted quickly for several reasons. Their efficiency, measured in watts of electricity per lumen of light, continued to improve, average lamp life increased, and prices came down as competition between manufacturers intensified. But their thermal efficiency made them, through a long chain of technical developments, ideally suited to open workspaces such as factories or open-plan offices. Crucially, their lower operating temperatures gave fixture designers a broader palette of materials. Incandescent lamps’ high bulb temperatures limited the materials that could be used to shade, focus, or diffuse their intense output. A glass globe could diffuse an incandescent lamp's brightness, but glass was heavy and expensive, and a globe trapped and converted more of the lamp's luminous energy into heat. More efficient louvers or baffles had to be fabricated from materials that could handle constant high temperatures. Glass and metals formed the basic material vocabulary for luminaires throughout the early 20th century, but material science in the 1930s offered new possibilities, in particular plastics. Here, the heat from incandescent lamps proved limiting; thermoplastic resins such as Bakelite, acetate, and polystyrene soften and deform at temperatures ranging from 127°F to 212°F—polystyrene's melting point is 248°F, just below the bulb temperature of a tungsten filament lamp. Thermosetting plastics such as melamine and acrylic can withstand higher temperatures without softening, but here, too, the high heat of incandescent lamps creates issues such as discoloration and brittleness; even acrylic has a service temperature of just 195°, making it unsuitable for incandescent luminaires. (28)

Architectural Record recognized the potential for plastics within cooler fluorescent luminaires in 1939:

"Plastics are lighter in weight than glass or metal, permitting savings in structural details, and greater safety in the use of overhead fixtures. They are less breakable than glass and less likely to crack from sudden temperature changes. Thickness, color, and shape can be controlled with precision, and optical characteristics can be varied to suit requirements as to transmission, reflection, and diffusion; but they are not practical for control by refraction. Some plastics can transfer light by internal reflection, like diffused quartz. The use of plastics with the larger filament lamps and with electric discharge sources is still limited because of inability to withstand the temperatures developed. They will probably be used more widely with the cooler fluorescent lamps." (29)

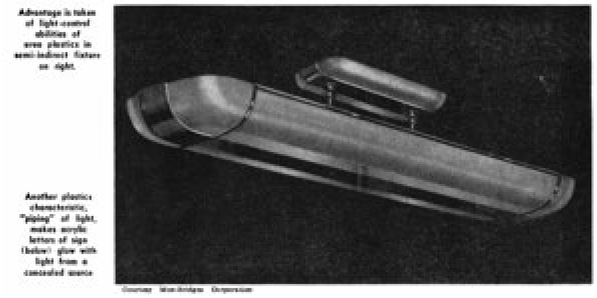

Fig. 3. Scientific American *was among the first to report on the possibilities of plastic in diffusing and directing the cool light of fluorescent lamps. "Partners in Light,"* May, 1946, 199.

Manufacturing technology for plastics developed during the war increased the range of possibilities in lighting design. By 1946, Underwriters Laboratories determined that "polystyrene and…other slow burning plastics" were suitable for use in fluorescent lamp fixtures. Thermoplastic materials offered great versatility. They could be produced in a range of opacities and could be molded or extruded into more precise, complex shapes than glass. This presented opportunities not only for shades and louvers, but also for lenses and diffusers that could take the place of the heavy, thermally massive glass globes that had surrounded incandescent lamps. Acrylic louvers and diffusers were matched by aluminum louvers and reflectors. Both materials were lighter and, after the war, less expensive than glass or steel. Scientific American predicted that plastics would "guide, blend, transport, and control light" in ways that would "be a stimulus to production, worker morale, and safety." (30) At the International Lighting Exposition in Chicago the next year, where fluorescent fixtures of all kinds demonstrated the surge of new applications and public acceptance of the new diffuse, cool light, exhibitors told the Chicago Tribune that "Plastics have largely replaced glass in fluorescent fixtures."

Plastics were critical in developing strategies for visual comfort in open work areas because of the lingering problem with glare from exposed lamps. While fluorescent lamps spread their light output over a greater area than incandescent lamps—a reduction of nearly 98% in direct foot-candles, according to one source—they remained too bright for office tasks. Such "light out of place" had been acceptable in factory installations where workers moved around, but for continuous visual tasks even minimal glare was deemed distracting and inefficient. Lighting designers addressed this by manipulating fixture locations relative to the ceiling and tuning fixtures to distribute some lamp light upward, recruiting bright white ceiling surfaces as giant reflectors. This indirect approach could be supplemented by louvers that blocked direct light at angles—suggested by experts to be anywhere from 15° to 45°--but that permitted light to directly illuminate surfaces below. This worked well in theory, since diffuse background lighting reduced eyestrain for more intensely-illuminated visual tasks, but in practice it proved difficult to balance the quantity of light emerging from the tops of fixtures with that directed downward. Research in the late 1930s suggested that, while a ceiling that was half as bright as the work surface would be most comfortable, louvering the bottom of a fixture and allowing lamps to illuminate the ceiling produced lighting levels there that were up to fifteen times brighter than desks below. (32) This was a consequence of simple room geometry; fixtures suspended from above needed to be placed well above head height, and building economics limited the potential for ceiling heights tall enough to balance interior lighting. In typical offices with ceiling heights of less than 10'-0", a light located at the accepted minimum for headroom, 6'-8", would be closer to the ceiling than to a 29"-high desk, and would therefore illuminate the ceiling more intensely. This imbalance was worsened if ceiling heights were lower, and high-rise construction, where every inch of building height is critical, placed particular pressure on these dimensions.

Luminaire design thus balanced several factors: preventing direct glare, balancing direct and indirect illumination, distributing light over work surfaces, and limiting impact on room cooling loads. Manufacturers responded with dozens of new fixtures that worked with fluorescent lamps' narrow, tubular geometry. While manufacturers and consumers had "become…accustomed to circular-shaped lighting equipment," the new lamps' long, narrow proportions, determined by the need to limit the distance from activating mercury vapor to fluorescing phosphorescent coating, created "more dominantly linear" solutions that suggested "lines of light," rather than points. (33) Fixtures incorporated reflecting and diffusing elements that could be extruded along the lamps' lengths, matching industrial processes of manufacturing plastics to the linear nature of the tubes themselves. Distribution of their light thus became a geometrical exercise in cross section, and a louvering or shielding one longitudinally. Aluminum, when polished, provided a lightweight, thin reflective surface that could be bent into precise parabolic shapes to focus light. It could also be cut into shading blades. Plastics such as acrylic could be molded or extruded into lens-like or prismatic patterns that could diffuse a tube's light evenly over a flat surface. Aluminum was lighter and allowed more specular surfaces and tighter detailing than steel while plastic matched aluminum's light weight with a range of opacities and colors that surpassed that of glass. Manufacturers began producing fixtures tuned to mounting locations below and within ceilings that either diffused or concentrated light in reliable patterns along their axes.

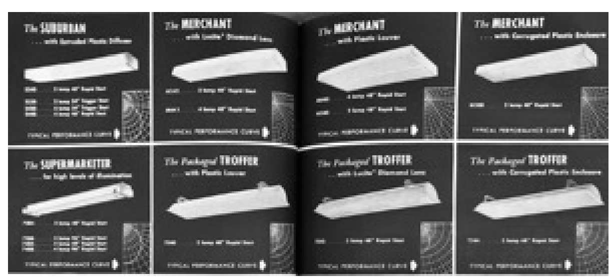

Fig. 4. The combination of easily extruded and molded plastic with the linear, diffuse nature of fluorescent lighting led to new fixture types that could be easily matched to the needs of new, open plan offices. Miller Company advertisement, Architectural Record*, May, 1955. xi.*

Standardized charts and tables of light distribution for individual fixtures enabled designers to accurately assess how many foot-candles could be thrown onto work surfaces or ceilings at varying angles. Lighting design became more of a science than art, with precise, predictable effects that could be obtained through a growing array of aluminum and plastic fixtures that focused, diffused, baffled, or concentrated light from fluorescent tubes.

The resulting precision was matched by a huge array of architectural possibilities. Linear fixtures could be arrayed in coves or cornices, for instance, providing even lighting over ceiling and wall planes. Attention focused, however, on the use of “troffers,” or flush-mounted ceiling units that combined a “trough” fixture with the intent of “coffer” lighting to provide an illuminated ceiling. These units could be arrayed in linear ranks across open offices and tuned, with lenses, reflectors, or adjustments in how many lamps each contained, to provide ideal background and task lighting along work surfaces and surrounding walls. Their regular march provided ceilings that were bright but comfortable, a key factor in the diffusion of the open plan offices and integrated, ‘power membrane’ ceilings that became trademarks of the next decades.

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